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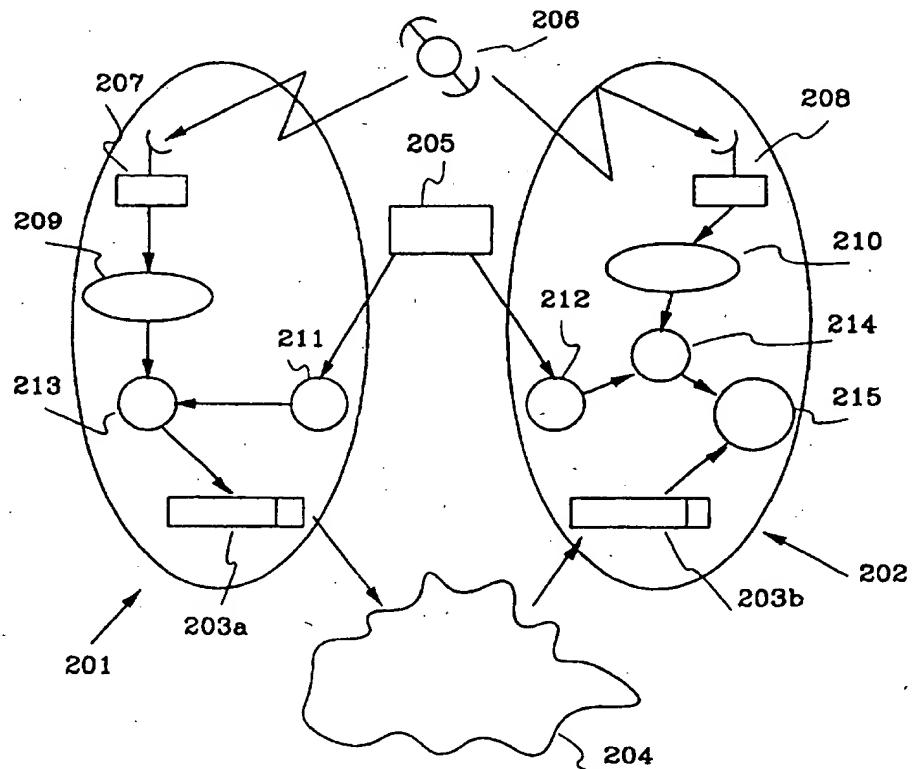**Published**
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(54) Title: METHOD AND APPARATUS FOR SYNCHRONIZATION OF TIME STAMPING

(57) Abstract

The present invention relates to an apparatus and a method for synchronization, of at least two time stamping clocks (213; 214; 310, 311) in a network, with high accuracy as well as a method for measuring transmitting delays of packets, with high accuracy. In more detail the present invention comprises a GPS-receiver (207; 307) which supplies TOD (Time of Day) and PPS (Pulse per second) to a synchronization function (209, 210; 308, 309). The synchronization function uses TOD to be able to calculate an absolute time for said time stamping clock. This arrangement allows for a synchronized absolute time between the time stamping clocks in the different nodes (101, 102; 201, 202; 301, 302) with a resolution of 1 second. The PPS pulse is used to synchronize the clocks with an accuracy of 1 microsecond. The time stamping clocks in the different nodes in the network is phase-locked to network-synchronization clocks (205; 305). By adjusting the frequency of the time stamping clocks a suitable resolution can be obtained within each second.

METHOD AND APPARATUS FOR SYNCHRONIZATION OF TIME STAMPING

FIELD OF INVENTION

5   The present invention relates to a method and to an
arrangement for synchronizing a time stamping clock in a
network with a high degree of accuracy, and to an arrangement
for measuring packet transmission delays in a network with a
high degree of accuracy.

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BACKGROUND OF THE INVENTION

Delays occur in packet switched networks when switching a
packet from one node in the network to another node. These
15   delays can vary very significantly and, among other things,
are due to the degree of utilization in the network and in
individual nodes, and also to the policy of different nodes
in forwarding a packet on arrival.

20   It is desirable to be able to measure the delays, so as to
enable a network to be trimmed or to ascertain which parts of
the network are subjected to greater or smaller delays, for
instance. Delays are measured by time stamping a packet, i.e.
by storing in the packet a value which represents the time at
25   which the packet leaves the node. The packet is then sent to
another node in the network, and this node reads the stored
value and compares the said value with the value on the time
stamping clock in the own node, i.e. so-called two-time
measuring. This provides a value of the delay. In order for
30   this method to function satisfactorily, the time stamping
clocks in the two nodes must show precisely the same absolute
time, i.e. they must be synchronized.

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In another delay measuring process, a one-time measuring
process, the receiving node need not itself calculate the
delay, and solely sends the packet immediately back to the
original node. The value stored in the packet is read in the
5   original node and compared with the current value of the
time stamping clock. This obviates the need to synchronize
two time stamping clocks, since only one time stamping clock
is used. The measurement value obtained shows the delay in
switching a packet to and fro. The delay in one direction is
10   obtained by dividing the value by two. This results in a very
good value, when delays are symmetrical. Unfortunately, this
is not often the case, since the packet can travel to and fro
along two different paths and in parts of the network that
have significantly different nodes. This is particularly
15   pronounced in the case of ATM networks (Asynchronous Transfer
Mode).

Examples of one-time and two-time measuring processes are CTD
(Cell Transfer Delay) and CDV (Cell Delay Variation).
20

In an ATM network, a performance management function (PM)
divides a number of packets into a block. A PM packet follows
each block and mediates different property related
magnitudes, which include the value of the time stamping
25   clock of the source node. This value is used in the target
node to measure delays. If a combination of a fast link, e.g.
622 MB/s, and a small block size, e.g. 128 packets, is used,
this will result in a large number of PM packets to the
target node. This places great demands on the process
30   capacity of the target node. The number of connections may
also contribute towards the requirement of processor
capacity.

Synchronization of time stamping clocks is a well-known problem in this field. NTP (Network Time Protocol) used to synchronize time stamping on the Internet can be quoted as an example in this respect. NTP has an accuracy of about one millisecond and is thus inadequate for ATM, for instance.

It is known from U.S. 5,280,629, Technique for Measuring Channel Delay, to use GPS equipment (Global Positioning System) to synchronize time stamping clocks for the purpose of measuring time delays between two nodes in a network.

One problem with the use of GPS for synchronizing time stamping clocks in accordance with U.S. 5,280,629 is that synchronization is lost very quickly if the GPS signal disappears, e.g. because of atmospheric interference and disturbances.

DISCLOSURE OF THE INVENTION

The present invention addresses the problem of how time stamping clocks can be synchronized in a network, preferably an ATM network, with sufficient accuracy and reliability.

Another problem addressed by the invention is how synchronization can be made insensitive to interference in GPS-equipment.

Another problem addressed by the present invention is how to provide a time value switching format that requires a minimum of processor capacity.

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Another problem addressed by the present invention is how delays in switching packets in a packet switched network, preferably an ATM network, can be measurted with sufficient accuracy and reliability.

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Accordingly, an object of the present invention is to synchronize time stamping clocks in different nodes in a network, preferably an ATM network, with sufficient accuracy and reliability.

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Another object is to enable packet switching delays in a packet switched network, preferably an ATM network, to be measured with sufficiently high precision and sufficient reliability.

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Still another object of the invention is to facilitate processing of time values switched between two nodes in a network.

20 In accordance with the present invention, these problems associated with the synchronization of time stamping clocks in different nodes in a network are solved in that the clocks are phase-locked to network-synchronization clocks, and in that the time stamping clocks obtain absolute time from a GPS

25 receiver.

The problem of facilitating processing of the time values is also solved in accordance with the present invention, by inserting in the transmission of said time values a format

30 that can be used directly to calculate time differences without translation.

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More specifically, the solution includes a GPS receiver that supplies TOD (Time Of Day) and PPS (Pulse Per Second) to a synchronization function. The synchronization function uses TOD to provide an absolute time for the time stamping clock in a node. There is thus obtained a synchronized absolute time between the time stamping clocks in the different nodes with a resolution of one second. The PPS pulse is used to obtain a degree of accuracy of one microsecond between the clocks. The clocks in the different nodes in the network are phase-locked to network synchronization clocks. The network synchronization clocks are clocked in the normal synchronization hierarchy of the physical interface in a telecommunications network. Since all network elements are phase-locked in the network synchronization hierarchy, it is guaranteed that all time stamping clocks will be phase-locked. Any chosen high resolution can be obtained within each second, by determining the frequency of the time stamping clocks. The accuracy of the absolute time is determined by the accuracy of PPS.

Because the time stamping clocks are phase-locked to the network synchronization clocks and not to the GPS, the time stamping clocks will continue to have a high degree of accuracy even if the GPS equipment should malfunction or if the signal from the GPS satellite should be disturbed.

One advantage afforded by the present invention is that synchronization of time stamping clocks is highly accurate and reliable.

Another advantage is that the invention is insensitive to faults in GPS equipment.

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Another advantage is that a large quantity of time values can be handled effectively at one and the same time, and that the absolute time can be obtained for transmission and reception.

5   The invention will now be described in more detail with reference to preferred embodiments thereof and also with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1 is an overview of a network according to one embodiment of the invention.

Figure 2 is a schematic illustration of one embodiment of the
15   invention.

Figure 3 is a schematic illustration of another embodiment of the invention.

20   Figure 4 is a block schematic illustrating sychronization.

DESCRIPTION OF PREFERRED EMBODIMENTS

The reference 101 in Figure 1 identifies a first node in a
25   network. The node 101 is a source node for measuring the delay in sending a packet 102 to a node 103, called the target node. The packet 102 is shown at a first time point in the node 101, and is there referenced 102a. At this time point, the value of the time stamping clock in node 101 is
30   stored in the packet and the packet is sent to a network 105 via the link 104. The network 105 is an ATM network in which the packet 102 passes a number of nodes before arriving at

the node 103 at a second time point 102b, via a link 106. The value of the time stamping clock is read in node 103 at the same time as the packet 102 arrives. This value is compared with the value stored in the packet 102, therewith enabling the delay to be calculated. Reference numeral 107 identifies a network synchronization clock in the network synchronization hierarchy.

It will be understood that although it would appear from Figure 1 that it is the same network synchronization clock 107 that supplies both nodes 101, 102 with pulses, such need not be the case. These pulses may equally as well be delivered by different, mutually phase-locked synchronization clocks that supply pulses to the various nodes in the network.

The time stamping clocks in the nodes 101 and 103 are phase-locked to the network synchronization clock 107. The nodes 101 and 103 also include GPS receivers for receiving a signal containing TOD and PPS from a GPS satellite 108.

In an ATM network, the time value is sent in a PM packet 102 in a field designated TSTP. The TSTP field consists in thirty-two bits and the time value is stored as the thirty-two least significant bits of the number of microseconds that have passed since 00:00:00 January 1, 1972. Since the time value is not coded when stored, the receiving node need only read and subtract in order to calculate time differences, for instance. This facilitates processing when calculating time delays, as distinct from the use of some form of code, such use increasing the calculating load on the processor.

Synchronization of the time stamping clocks will be seen more
readily from Figure 2. A node 201 is a source node in
measuring delays between node 201 and a node 202. Node 202 is
the target node in the delay measuring process. A packet 203

5   is switched over an ATM network 204. Numeral 205 identifies a
network synchronization clock, while numeral 206 identifies a
TPS satellite. Similar to the embodiment illustrated in
Figure 1, the nodes 201 and 202 may be supplied with pulses
from two physically different but mutually phase-locked

10   network synchronization clocks in the Figure 2 embodiment. A
comparison between the numbering in Figure 1 and in Figure 2
is given in the following Table:

	Fig. 1	Fig. 2	Fig. 3
15	**Source node**	101	201	301
Target node	103	202	302
Packet	102	203	303
ATM network	105	204	304
20	**Network synchronization clock**	107	205	305
GPS satellite	108	206	306

The numeral 207 identifies a GPS receiver in node 201. The
25   receiver 207 receives TOD and PPS from a signal sent by the
GPS satellite 206. Similarly, a GPS receiver 208 in the node
202 receives TOD and PPS from the same GPS satellite 206. The
GPS receiver 207 sends to a synchronization function 209
information relating to TOD and PPS. The function 209 stores
30   the value of TOD in a data store that forms a part of a time
stamping clock 213. A synchronization function 210 in node
202 functions in a similar manner with a time stamping clock

214. By storing TOD plus one second precisely when the next PPS is received, there is obtained an absolute time which is identical in all nodes to a degree of accuracy of one microsecond. TOD is obtained from the GPS satellite 206 with a resolution of one second and PPS is obtained with a degree of accuracy of one microsecond or better. A PLL (Phase Locked Loop) 211, 212 in each node 201, 202 is phase-locked to the network synchronization clock 205 in the network synchronization hierarchy. The PLLs 211, 212 deliver a pulse train to the time stamping clocks 213, 214. The time stamping clocks 213, 214 are counted up with each pulse that arrives. When the PLLs 211, 212 have a frequency of 1 Mhz, each upcount corresponds to one microsecond.

The accuracy of the PPS signal depends on a number of different things, inter alia the receiver equipment used and on different types of corrections. It can be said that, as a rule, the lowest degree of accuracy achieved is one microsecond, although much better values can be obtained with refined instruments and positional stipulations.?

The time stamping clocks 213, 214 are synchronized relatively seldomly, i.e. when a new TOD value is stored, e.g. between once every ten minutes and once every calendar day. Synchronization can result in an error if the PLLs 211, 212 do not have precisely the same frequency as a GPS, for instance, the PLLs 211, 212 may only have counted 999 microseconds when the next PPS pulse arrives. This results in a gap? of one microsecond. This error can be rectified in a number of different ways. For instance, a message can be sent with the next packet intended for delay measurement that indicates that synchronization has been carried out. Another

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option is to ignore the error, since the effects of a large number of measurements disappear. A third option is to synchronize often enough for the error to be smaller than one microsecond, which will not then influence the measurement.

In the illustrated embodiment, the PPLs 211, 212 have a frequency of 1 Mhz and by keeping it phase-locked to the network synchronization clock 205, it will be guaranteed that all time stamping clocks keep the same time. The PPL 211 delivers a pulse to the time stamping clock 213 every microsecond. The above-described time measurements are combined to obtain a time stamping clock having a resolution and accuracy of one microsecond. The millisecond and microsecond parts of the time value are counted up by the PLL 211 and the absolute time of TOD and PPS is obtained in the synchronization. The PLL 212 functions in a corresponding manner in the node 202.

In another embodiment, the PLLs 211, 212 have a frequency of 10 Mhz. This results in a difference between the absolute resolution and the relative resolution. The absolute resolution will still be one microsecond given by the PPS signal, meaning that the resolution for measuring absolute time delays is still one microsecond. On the other hand, all relative magnitudes can be measured with a resolution of 0.1 microsecond, e.g. delay variations, CDV.

Because the PLLs 211 and 212 are phase-locked to the network synchronization hierarchy, a PPS pulse is not necessary in maintaining the accuracy of the PLLs 211 and 212. Even though the PPS pulse may disappear, the PLLs 211 and 212 will remain synchronized for a very long period of time.

When the packet 203 arrives at the node 202, a comparison
function 215 reads the time value from the packet 203 and
compares this value with the value of the time stamping clock
214. This enables CDV and CTD to be calculated, for instance.

5

The embodiment illustrated in Figure 3 also lacks the use of
a PLL, and two time stamping clocks 310, 311 obtain pulses
directly from a network synchronization clock 305 in the
network synchronization hierarchy. Similar to the embodiments
10   of Figures 1 and 2, the various nodes 301, 302 in the Figure
3 embodiment may also be provided with pulses by two
physically different but mutually phase-locked network
synchronization clocks. In the Figure 3 embodiment, a GPS
receiver 307 is centralized by being localized in a node 313.
15   The fact that the GPS receiver 307 is able to switch the GPS
signal from a satellite 306 to two nodes 301 and 302 without
losing the accuracy in the PPS signal enables synchronization
to be implemented with sufficient accuracy. This embodiment
is analogous with the aforedescribed embodiments in other
20   respects. A synchronization function 308 coordinates TOD, PPS
and pulses from the network synchronization clock 305 in the
time stamping clock 310, which stores a time value in a
packet 303. Figure 3 shows the packet 303 in a first time
point coh and is there referenced 303a and at a second time
25   point, where it is referenced 303b. The packet 303 is sent to
the node 302 via a network 304, and the time value stored in
the packet is read in said node. A comparison function 312
compares the value of a time stamping clock 311 localized in
the node 302 with the time value obtained from the packet
30   303. The comparison function 312 is then able to calculate
CDT, CDV and other data of interest. A synchronization

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function 309 coordinates TOD, PPS and pulses in the node 302, in the same way as the node 301.

Figure 4 shows in detail combination of TOD, PPS and the
5   signal from the PLL. Numeral 401 identifies a counter which is stepped for each pulse on an input 402. A pulse train arrives on the input 402 from the PLL 211 in Figure 2, or directly from the network synchronization clock 305 in Figure 3 in the network synchronization hierarchy. Numeral 403
10   identifies a register in which TOD information is stored. When TOD arrives from the GPS signal, the value of the obtained TOD with the addition of one second is stored in the register 403. A signal 404 is set to one, which enables a Q-output 405 to be set to one, and when the next PPS pulse
15   arrives on the input 406 both inputs of the AND gate 408 are ones, which gives a one on a latch-input 407 and the value TOD register 403 is written into the counter 401.

It will be understood that the invention is not restricted to
20   the aforedescribed and illustrated embodiments thereof, and that modifications can be made within the scope of the following Claims.

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CLAIMS

1.   A method of synchronizing at least one time stamping clock with a number of other time stamping clocks in a network, **characterized** in that pulses arrive at said time stamping clock (213, 214; 310, 311) at regular intervals; in that a GPS receiver (207, 208; 307) sends PPS information (Pulse Per Second) and TOD information (Time Of Day) to a synchronization function (209, 210; 308, 309); and in that said synchronization function calculates the value of said time stamping clock from PPS, TOD and pulses.

2.   A method according to Claim 1, **characterized** in that a PLL (211, 212) sends pulses to the time stamping clock (213, 214); and in that said PLL phase-locks to a network synchronization clock (205).

3.   A method according to Claim 1, **characterized** in that a network synchronization clock (305) sends pulses directly to said time stamping clock (310, 311).

4.   A method according to Claim 2, **characterized** in that said PLL (211, 212) sends pulses to said time stamping clock (213, 214) at a frequency of 1 Mhz.

5.   A method according to Claim 2, **characterized** in that said PLL (211, 212) sends pulses to said time stamping clock (213, 214) at a frequency of 10 Mhz.

6.   A method according to Claim 1, **characterized** in that said synchronization function (209, 210; 308, 309) stores TOD plus one second in a register (403); in that said

synchronization function enables data to be written in a counter (401) subsequent to having stored TOD plus one second in said register; in that the value of said register is written into said counter upon the arrival of the next PPS; in that writing of the value of said register into said counter makes writing into said second register impossible; and in that said counter is stepped with each pulse received.

7.   An arrangement for synchronizing at least one time stamping clock in a first node with a number of second time stamping clocks, **characterized** by at least one network synchronization clock (107; 205; 305); in that said first node (101, 103; 210, 202; 301, 302) includes means for receiving a GPS signal that contains TOD information and PPS information; in that said first node includes pulse receiving means; and in that said first node includes a synchronizing function (209, 210; 308, 309) for coordinating said pulses with TOD and PPS for calculating the value of said time stamping clock (213, 214; 310, 311).

8.   An arrangement according to Claim 7, **characterized** in that a PLL (211, 212) is connected to said network synchronization clock (205); and in that said PLL is connected to said time stamping clock (213, 214).

9.   An arrangement according to Claim 7, **characterized** in that said time stamping clock (310, 311) is connected directly to said network synchronization clock (305).

10. An arrangement according to Claim 7, **characterized** in that said first node (201, 202) includes a GPS receiver (207,

208); and in that said GPS receiver is connected to said synchronization function (209, 210; 308, 309).

11. An arrangement according to Claim 7, **characterized in** that a second node (313) includes a GPS receiver (307); and in that said GPS receiver is connected to said synchronization function (209, 210; 308, 309).

12. An arrangement for measuring delays when switching packets in a network, said network including at least two nodes, **characterized** in that the network (105; 204; 304) includes at least one network synchronization clock (107; 205; 305); in that said nodes (101, 103; 201, 202; 301, 302) include means for receiving TOD and PPS from a GPS signal; in that said nodes include pulse receiving means; in that said nodes include a synchronization function (209, 210; 308, 309) for coordinating said pulses with TOD and PPS for calculating the value of a time stamping clock (213, 214; 310, 311) localized in each node; in that the first node (101; 201; 301) includes means for storing in a packet (102; 203; 303) a time value of said time stamping clock and means for switching said packet over said network to said second node (103; 202; 302); in that said second node includes means for reading the time value in the packet; and in that said second node includes means (215; 312) for comparing the time value read from the packet with a time value of the time stamping clock (214; 311) in said second node.

13. An arrangement according to Claim 12, **characterized in** that a PLL (211, 212) is connected to said network synchronization clock (205); and in that said PLL is connected to said time stamping clock (213, 214).

14. An arrangement according to Claim 12, **characterized** in that said time stamping clock (310, 311) is connected directly to said network synchronization clock (305).

5   15. An arrangement according to Claim 12, **characterized** by a GPS receiver (207, 208) located in each node (201, 202); and in that said GPS receiver is connected to said synchronization function (209, 210; 308, 309).

10   16. An arrangement according to Claim 12, **characterized** by a third node (313) that includes a GPS receiver (307); and in that said GPS receiver is connected to said first node (301) and to said second node (302).

15   17. An arrangement according to Claim 12, **characterized** in that the time value is stored in the packet as the thirty-two least significant bits of the number that represents the number of microseconds that have passed since 00:00:00 January 1, 1972.

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1/4
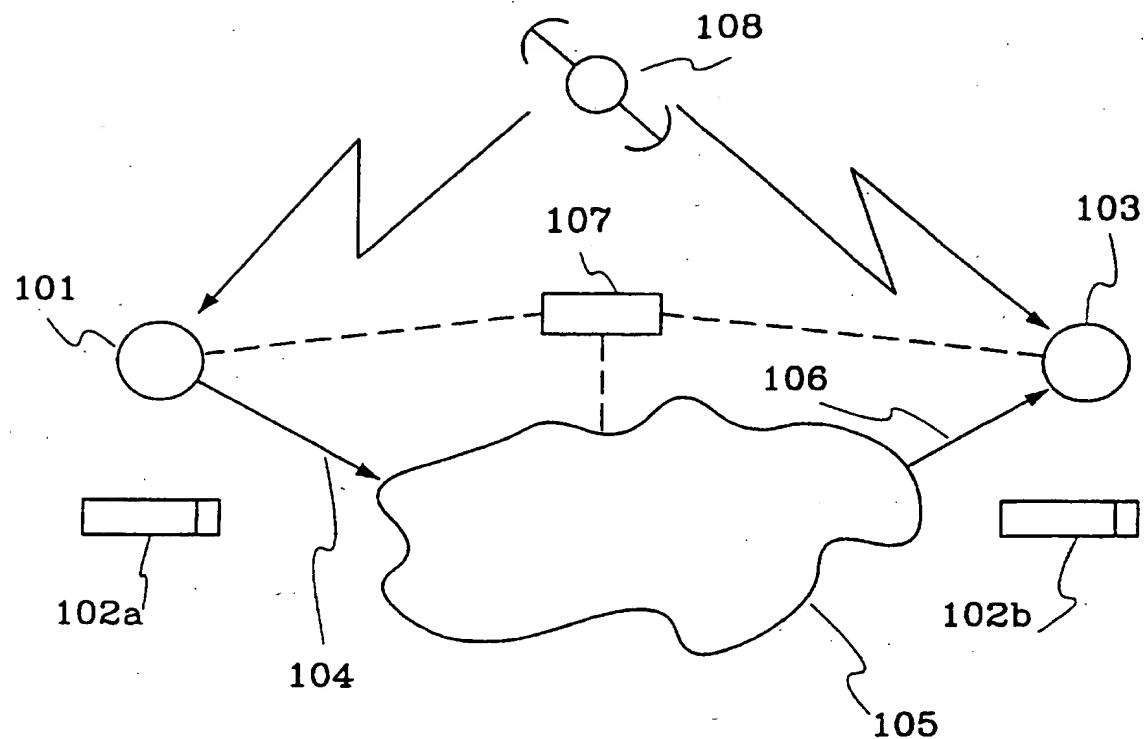
Fig. 1

2/4

Fig. 2

3/4

Fig. 3

4/4

TOD+1s
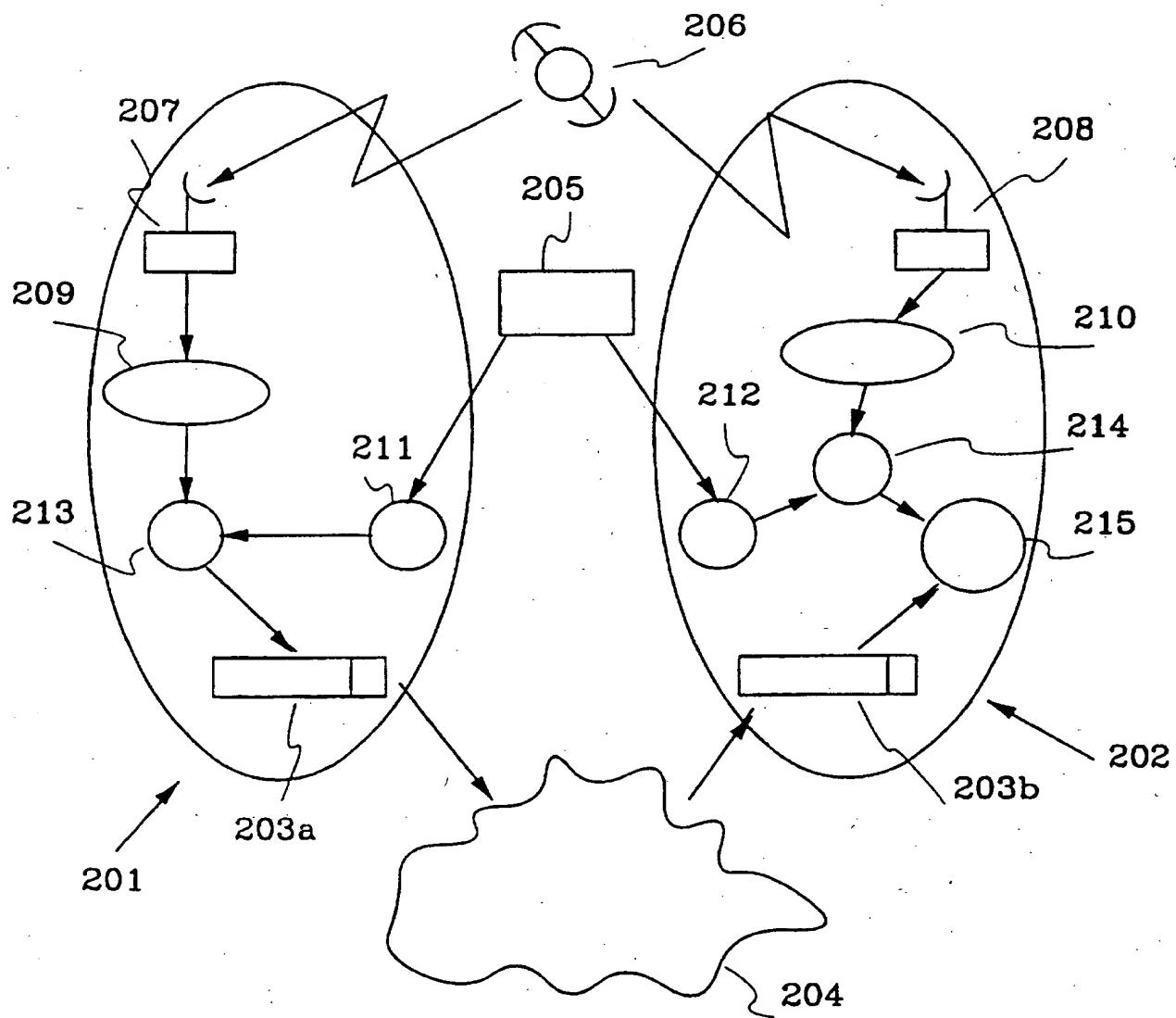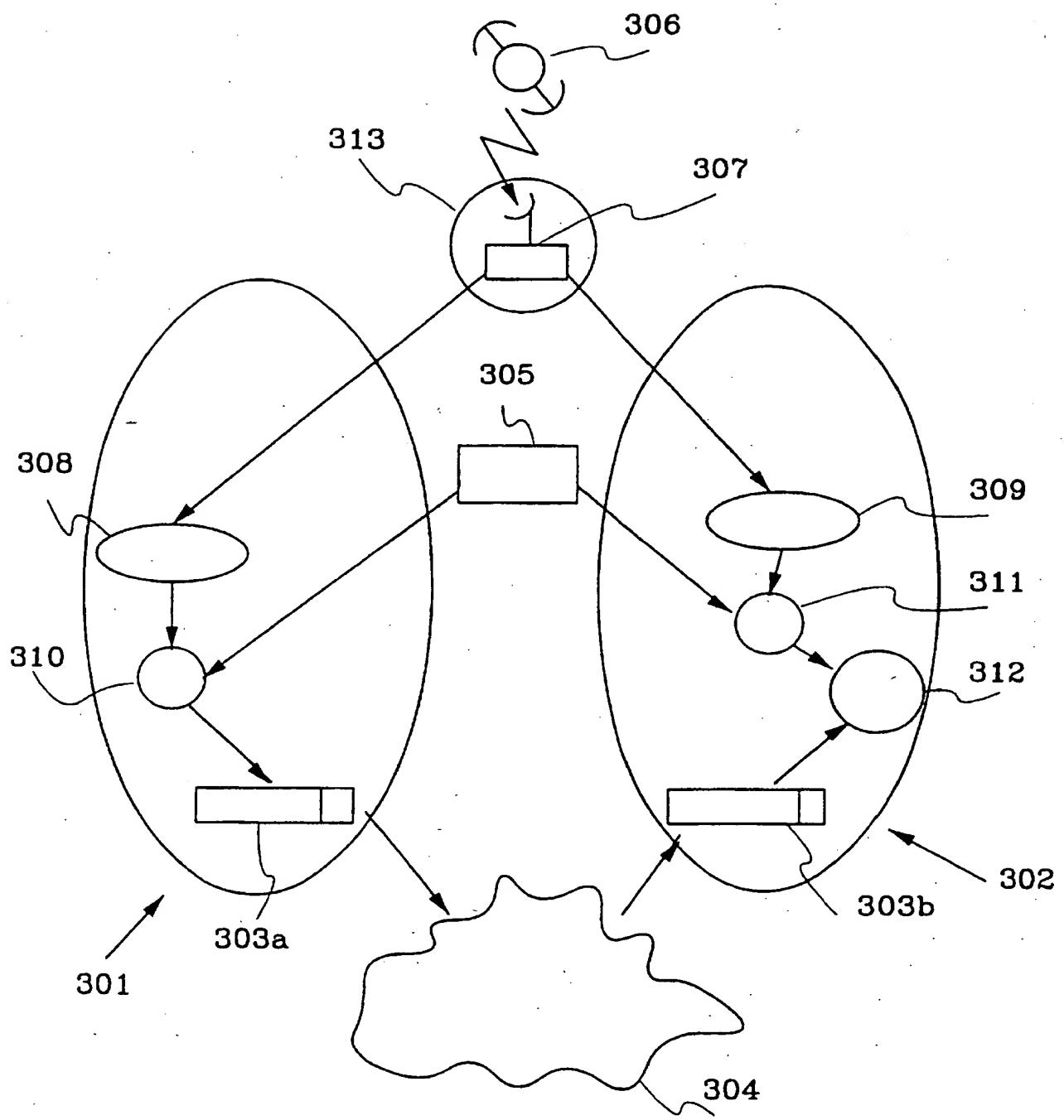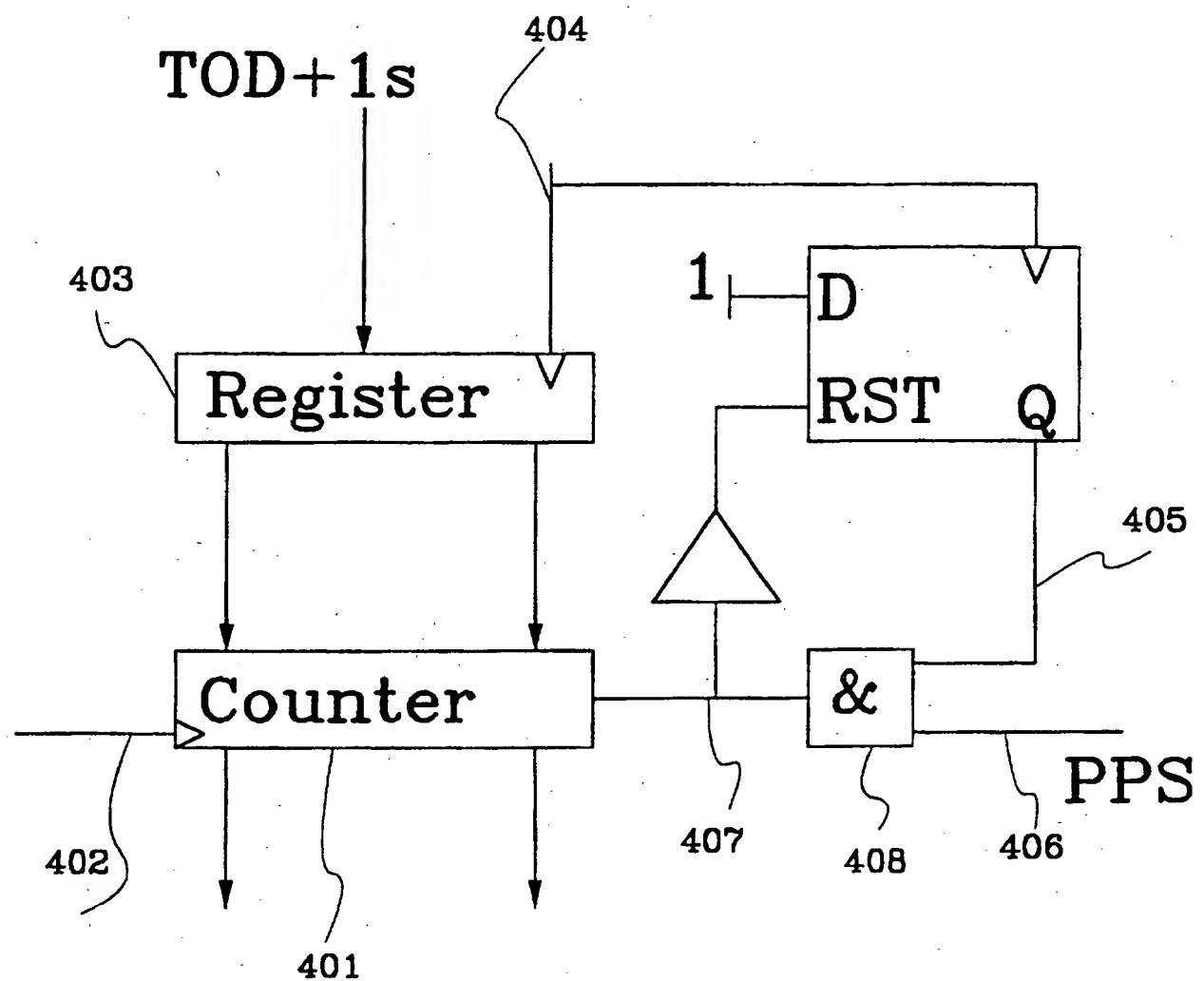
Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 97/01537

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H04L 7/08 // H04L 12/56

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H04L, H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPIL, EDOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A		2,4,5,8,13
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Y	US 5280629 A (ROBERT D. LO GALBO ET AL), 18 January 1994 (18.01.94), column 2, line 46 - column 4, line 47, abstract	1,3,6,7, 9-12,14-17
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☒ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

Date of the actual completion of the international search	Date of mailing of the international search report
26 February 1998	02 -03- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Anders Ströbeck Telephone No. +46 8 782 25 00

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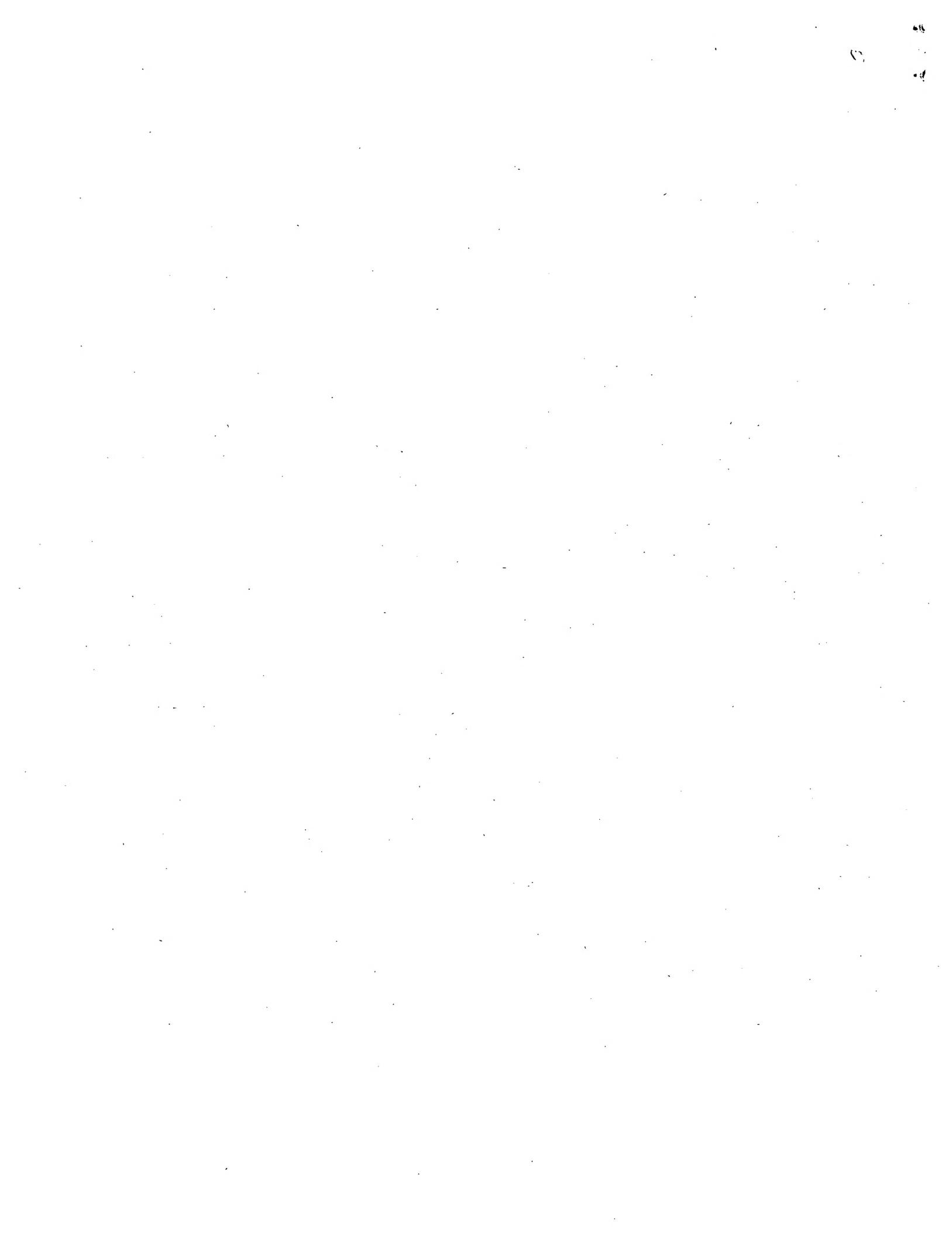| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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